

Effect of Oral Functionality on Human Masticatory Muscle SEMG

*A Dissertation submitted in partial fulfilment of the requirements for
the award of degree of*

**Master of Engineering
in
Electronics Instrumentation and Control**



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CERTIFICATE

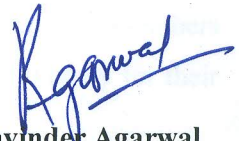
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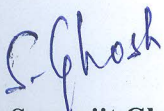
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ABSTRACT

SEMG is non invasive method which is being used to study the myoelectric activities of human skeletal muscle. SEMG stands for surface electromyogram. SEMG signal is measured from the surface of skin. Various movements of muscles can be correlated with SEMG activity. In the current research work SEMG signal is analyzed for human masticatory muscles. Masticatory muscles are those muscles which are responsible for various oral functions such as chewing, swallowing, and biting. SEMG in dentistry is still not studied in detail. Still now in dentistry for the evaluation of oral functionality strain gauges are used by putting inside the mouth to evaluate the oral functions in terms of pressure exerted on strain gauge. It is neither subject friendly approach nor economical. Therefore, a new method has been used and analysed for the SEMG masticatory muscles activities

In this research work SEMG signals were acquired from three jaw muscles that are temporalis, masseter and submental with help of surface electrode and LabVIEW for different normal oral activities. Thereafter RMS, MAV, SSI, VAR, Power Spectrum were calculated. Result shows that temporalis muscle had the highest activity and the masseter muscle has signal lower than temporalis. The Both two muscle shows same pattern. The submental muscle had the highest activity/signal in water drinking. Submental muscle has the lowest SEMG activity as compared to other two muscles.

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List of Abbreviations

EMG	-	Electromyography
SEMG	-	Surface Electromyography
TMJ	-	Temporomandibular Joint
NI-DAQ	-	National Instrument Data Acquisition Card
LabVIEW	-	Laboratory Virtual Instrument Engineering Workbench
RMS	-	Root Mean Square
MAV	-	Mean Absolute Value
SSI	-	Simple Square Integral
VAR	-	Variance

Chapter 1

Introduction

1.1 Overview

SEMG is a non invasive method use to study myoelectric activity of skeletal muscles. These muscles are responsible for voluntary movements which are controlled by nervous system through neurons. The main advantage of SEMG is that there is no need of a medical professional. Surface EMG is generally accepted as the gold standard for overall muscle function [1]. With the development of surface electrodes and techniques for analysing of SEMG signal, its importance becomes more and more. But still if there is need to study the activity of a specific muscle then the use of needle electrodes is inevitable. This must be done under supervision of a professional. In this study SEMG technique was used.

SEMG in dentistry is still not widely used. By observing the SEMG patterns of the human masticatory muscles one can evaluate various oral functions and also diagnose of various muscles pain in jaw. In several circumstances the masticatory muscles may become tender to sensation of fatigue, pain and discomfort whose underlying mechanism is still largely unknown. Before the development of EMG the muscle pain in jaw is evaluated by pressure exerted by it inside the mouth. The pressure is measured by using strain gauge inside the mouth. This method has various disadvantages. All these measurements can be done by SEMG with proper technique [2].

1.2 Objective

In this study main objective is to pickup and analyze the SEMG signal from three human masticatory muscles that are temporalis, masseter and submental muscles for various oral activities like chewing, swallowing, isometric clenching etc. for assessment of oral functions.

1.3 Dissertation Orientation

- Chapter 1 “**Introduction**”, it includes the introduction about the overview and objective of this dissertation

- Chapter 2 “**Literature Survey**”, it provides the overview of work done in this area.
- Chapter 3 “**Surface Electromyography and Jaw Anatomy**”, it gives the basics of SEMG, its usefulness in dentistry and points in human jaw from where SEMG signals were picked in this study.
- Chapter 4 “**Materials and Methods**”, this chapter discuss about various tools, software, materials and methods that were used for pickup and analyzing SEMG signal.
- Chapter 5 “**Results and Discussions**”, results that were obtained discussed in this chapter.

Chapter 2

Literature Review

Budyanski Thomas *et al.* [3], an electromyography feedback technique was developed for muscle relaxation exercise. In this study the subject received the visual or auditory feedback of his electromyography activity. Out of eighty subjects only forty subjects received feedback. The subjects who received the feedback reduced their masseter electromyographic activity up to a great extent as compare to subjects who did not received feedback. This technique could be applied to persons who are suffering from various dental disorders such as bruxism and temporomandibular myofascial pain dysfunction, in which the contraction of the jaw musculature is excessive or sustained for too long.

Majewski R.F *et al.* [4], the EMG activity of anterior temporal and non specific facial muscle were recorded from 11 subjects who had unilateral anterior area muscle pain and from 11 matched individuals at various mandibular openings. It was observed that no significant difference was found between EMG activity of pain and non pain temporal area muscle of both group. Same results were found for non specific facial muscle. With relation to mouth's vertical opening EMG of both tempoarlis and non specific facial muscle was at minimum level. Subjects were asked to keep eyes closed during whole process to avoid artifacts in temporal area due to eye moments.

Yuen S.H.W. *et al.* [5], the frequency domain analysis was used to study the EMG activity. The EMG activity of masseter and anterior temporalis muscle from children and adults of both then sexes were recorded. EMG power spectrum was used to calculate the mean power frequency. The result shows that significant difference between age and sex was found. Male adult had the lowest mean power frequency and female had the highest. The reason for this was given that difference between muscle during growth and development of the craniofacial morphology.

Lindauer S.J. *et al.* [6], the purpose of this study was to find the utility of EMG force characteristic parameter to access oral functionality. The EMG activity of masseter muscle was recorded at two separate occasions at various mandibular openings and force level. Then the reproducibility of EMG was checked. The results shoes that 1) There were

variations in EMG values between individuals; 2) At higher forces level EMG was reproducible; 3) The slope of an EMG- force curve is a reproducible and reliable parameter to access the EMG activity for oral functionality; 4) The EMG force y intercept is not a good parameter to study for oral functions.

Visser A. *Et al.* [7], the surface EMG recordings were made and investigated from masseter and the anterior and posterior parts of temporalis muscle with different jaw openings and saggital jaw relation. EMG activity from 10 subjects recorded at 10% and 50% of their maximum voluntary clenching level. At the 10% clenching level activity of temporalis level decrease after the vertical dimension were raised. At 50% clenching level, a decrease in activity only in one condition out of four was observed. The EMG activity of masseter was same at both levels and on all jaw position.

Lindauer S.J. *et al.* [8], this study investigates the change in EMG activity of masticatory muscle in bite force at various bite openings. EMG activities were recorded from masseter and anterior, middle, posterior temporalis muscle. Significant increase of EMG activity was noted in posterior temporalis muscle with increase in bite force. In all four muscles masseter shows greatest increase. The other muscle also reported change in activity with bite force and vertical openings. This change was observed due to change in muscle length with change in vertical openings. The reason for bite force was given that it can be affected by biomechanical factors and neural control adaptation.

Fogle L.L. *et al.* [9], in this study canonical correlation was used to investigate the effect of age, gender, and facial morphology was studied. EMG readings were taken at various biting and resting condition. The results showed that age and gender affect not the facial morphology.

Gallo L.M. *et al.* [10], in this study an automatic one channel on line recognition system was developed to recognize various oral activities. Series of activities were performed on 12 subjects and EMG of activity of masseter muscle was recorded. Chewing soft food was recognized 97% of times and speaking was 86% of times. All other activities were recognized 99% of times. The results show that system has high reliability and sensitivity. This algorithm can be use for classification of oral activities under laboratory conditions.

Agrawal K.R. *et al.* [11], the effect of food properties that are toughness a modulus of elasticity on EMG activity during mastication was studied. The subjects were asked to eat

15 types of food of fixed quantity. The EMG activity of anterior temporal muscle was recorded at each occasion. The integrated EMG was directly related to the square root of the ratio of two described food properties. For the first time relation between food properties and EMG activity of masticatory muscle was found.

Fontijn – Tekamp F.A. *et al.* [12], in this study the EMG activity of biting and chewing in overdentures, full dentures and natural dentition were observed. All three groups performed same set of activities. Results shows that bite forces that were generated with overdentures were in between artificial denture and natural dentition. The difference in activities within various types of overdentures was due length of dental arc and occlusal area. A significant correlation was found between maximum bite force and chewing efficiency when all groups were combined.

Proeschel P.A. *et al.* [13], the EMG activities were recorded of four elevators muscles during various mastication activities. The value of force was also recorded for these activities on a bite fork. Then the EMG activities were used to estimates the bite force. Only balancing side masseter, the activity/bite force ratio was significantly higher in chewing than in biting. The force was estimated from EMG was 273N to 475N. While the actual mean of chewing force was 220N. The result indicates that EMG overestimates the force.

Chung J.W. *et al.* [14], in this study the change in median frequency of power spectra of masseter and anterior temporalis muscle in both genders were investigated. No difference was found related to gender. Within muscle comparison shows that temporalis muscle has higher median frequency, shorter duration, less number of phases and decreased area.

Chen Li *et al.* [15], the subjects were divided in tree groups in three equal numbers as implant tooth supported overdentures (ISO), tooth supported overdentures (TSO) and complete denture (CD). Their EMG activity was recorded to study the comparative masticatory efficiency (CME). Tracing of mandibular excrusion (ME) and EMG activity were analyzed. The results showed that CD has lowest efficiency and ISO has greatest efficiency.

Kampen Van F.M.C *et al.* [16], in this study with in subject effect of various type of attachments in ISO. Eighteen edentulous subjects were selected. Each subjects received 2 oral implant, a new overdentures, and successively 3 different suprastructures modalities:

magnet, ball, and bar clip. Swallowing threshold, masticatory efficiency and masticatory performance was measured. The masticatory function showed significant improvement after implant treatment with each of three attachments. Small differences were observed in masticatory functions among three attachment types. It is concluded that slightly smaller number of chewing cycles combined with a better masticatory performance after implant treatment.

Neyraud E. *Et al.* [17], the effect of bitter taste on mastication pattern was studied with the EMG activity. The different test foods were prepared of sweet to bitter taste by increasing amount of quinine in food items. As bitterness increased average clearance time increased from 7 to 14 seconds and number of chewing strokes decreased to 30 to 22. The result shows that change in taste affects the breakdown of food in mouth.

Kornard Peter [18], this study gives deep insight of EMG activity. All basics were covered in this study from acquisition to analysis of EMG signal.

A. Palumbo *et al.* [19], a system was developed which can acquire multiple signal from masticatory muscles such as bite force, muscle pain and EMG activity. Ten subjects were ask to clench at various forces level for a prolong time. The EMG activity was recorded from paired masseter and temporalis muscle. Then the bite force and muscle pain were investigated from EMG activity. The system was flexible and efficient to describe the muscle pain and bite force. Even in some subjects the system was able to describe the switch of activity between muscles.

Goiato Coelho Marcelo *et al.* [20], the EMG activity was recorded from masseter and anterior temporal muscle in patients with severe bone resorption, with complete dentures worn for over ten years, five months after having new dentures in place. The EMG readings were taken at rest and maximum tooth clenching. The EMG activity of rest of both the muscles shows no statistically significant difference after five months of wearing new complete dentures. The right side of temporal muscle shows significant reduction in EMG activity. Thus a period of five months was required for adaptation of new complete dentures.

Felix Berretin Giedre *et al.* [21], ten females and five males were selected who wore complete dentures on both the dental arch. They received implant supported prosthesis on mandibular dentures. The EMG activity of mastication muscle and submental muscle

were recorded before surgery and 3,6,18 months postoperatively. With different foods texture. After surgery masseter muscle show decrease in EMG activity while swallowing. This means subjects were adapting to implants.

Monaco Annalisa *et al.* [22], in this study the EMG activity of jaw elevators muscle, submental muscles and neck muscles were recorded during swallowing of saliva and water. The subjects were divided in two groups as who swallowed without occlusal contact (SNOC) and had occlusal contact (SOC). The results showed that activity of jaw elevators muscles show significant difference. Significantly higher duration was observed in SNOC group. Gender has no effect on EMG but healthy SOC and SNOC group has different swallowing pattern.

Catelli DS *et al.* [23], this study shows the usefulness of characteristics of power spectra to analyze EMG. The median frequency and F95 parameter proved to be good parameters to study EMG activity. These parameters can be applied intersubject and within muscle to determine healthy person and unfit person.

Surface Electromyography and Jaw Anatomy

3.1 Introduction

There are three types of muscles in human body namely, skeletal, smooth and cardiac. Cardiac and smooth muscles are responsible for all the involuntary motions, like beating of heart, motion of intestine. Skeletal muscles are responsible for voluntary motions. Electromyography is a technique of measuring and recording of electrical activity of skeletal muscle. EMG signal is a measure of electrical currents generated in skeletal muscles during its contraction, which is generated by electrical impulses transmitted by nerves. The muscle activity (contraction/relaxation) is always controlled by nervous system. It's a complex and random signal, which is controlled by the nervous system and is dependent on the anatomical and physiological properties of muscles. These EMG signal acquires noise while travelling through different parts of body. When this signal is collected from the surface of the skin then it is called as Surface Electromyography. EMG is sometimes referred to as myoelectric activity [24].

3.2 History

The development of EMG started with Francesco Redi's documentation in 1666. The document informs that highly specialized muscle of the electric ray fish generates electricity. By 1773, Walsh had been able to demonstrate that Eel fish's muscle tissue could generate a spark of electricity. In 1792, a publication entitled "De Viribus Electricitatis in Motu Musculari Commentarius" appeared, written by A. Galvani, where the author showed that electricity could initiate muscle contractions. Six decades later, in 1849, Dubios-Raymond discovered that it was also possible to record electrical activity during a voluntary muscle contraction. The first recording of this activity was made by Marey in 1890, who also introduced the term electromyography. In 1922, Gasser and Erlanger used an oscilloscope to show the electrical signals from muscles. Because of the stochastic nature of the myoelectric signal, only rough information could be obtained from its observation. The capability of detecting electromyographic signals improved steadily from the 1930s through the 1950s and researchers began to use improved electrodes more widely for the study of muscles. Clinical use of surface EMG for the treatment of more specific disorders began in the 1960s. Hardyck and his researchers

were the first (1966) practitioners to use SEMG. In the early 1980s, Cram and Steger introduced a clinical method for scanning a variety of muscles using an EMG sensing device. It is not until the middle of the 1980s that integration techniques in electrodes had sufficiently advanced to allow batch production of the required small and lightweight instrumentation and amplifiers. At present a number of suitable amplifiers are commercially available. In the early 1980s, cables became available which produce artifacts in the desired microvolt range. During the past 15 years, research has resulted in a better understanding of the properties of surface EMG recording. In recent years, surface electromyography is increasingly used for recording from superficial muscles in clinical protocols, where intramuscular electrodes are used for deep muscle only [24].

3.3 Source of EMG Signal

The human body as a whole is electrically neutral; it has the same number of positive and negative charges. But in the resting state, the nerve cell membrane is polarized due to differences in the concentrations and ionic composition across the plasma membrane. An ionic equilibrium between the inner and outer spaces of a muscle cell forms a resting potential at the muscle fibre membrane approximately of -80 to -90 mV. Thus a potential difference exists between the intra-cellular and extra-cellular fluids of the cell. In response to a stimulus from the neuron, a muscle fibre depolarizes as the signal propagates along its surface and the fibre twitches. This depolarization, accompanied by a movement of ions, generates an electric field near each muscle fibre which is an electromyogram. The measured potential can be less than 50 μ v and may go up to 20 to 30 mV. The frequency range of an EMG signal is 2-10 KHz [18].

3.4 EMG Procedure

There are two types of electrodes used in EMG – surface and needle type. Needle electrodes are directly inserted in muscle of interest after piercing the skin and this must be done under supervision of a medical professional. Needle electrodes are used only if particular muscle tissue is to be studied. Surface electrodes are used when group of muscles is to be studied. In this study only surface electrodes were used, as they do not require a medical professional. Motor unit is defined as one motor neuron and all of the muscles get electrical signal from it for their activation. When a motor unit fires, the electric impulse travels down to the muscle. The area where the nerve contacts the muscle

is called the neuromuscular junction. After the electric impulse in form of action potential is transmitted across the neuromuscular junction, it spreads to all of the connected muscle fibres of that particular motor unit. The addition of all this electrical activity is known as motor unit action potential (MUAP). What the surface electrode of EMG picks up is the sum of many MUAPs of that area. Hence the EMG signal sensed by the surface electrode depends upon numbers of factors such as composition of the motor unit, the number of muscle fibres per motor unit and the metabolic type of muscle fibres. When a subject is at rest or one can say that when a muscle tissue is at rest, it means tissue is largely electrically inactive. In this condition electrode will not pick up any signal from muscle. When subject is asked to contract muscle then signal will be detected. The amplitude of signal will be depending upon extent of contraction, as more and more muscle fibre produce action potential.

3.5 Surface Electrodes

Electrodes come in different shapes and sizes. Basically they can be divided as disposables and active electrode.

- 1) Disposable electrode – They eliminate the requirement for cleaning and care of electrode after each use. In general, disposable are of floating type with simple snap connectors by which the leads, which are reusable, are attached. Although some disposable electrodes can be reused several times, their cost is usually low enough that for reuse is not warranted. They come pregelled, ready for immediate use. Silver chloride electrodes (AgCl) generally use as disposable electrodes. These electrodes are only use for pickup the SEMG signal from body. Then SEMG signal is amplified before any kind of signal processing. This type of electrode was used in this study. Figure 3.1 shows disposable electrodes.



Figure 3.1 Disposable Electrodes

- 2) Active electrodes – In most EMG readings passive electrodes are used. They are cheap, easy to manufacture and maintenance. They usually require however special skin preparation in the spot under electrode to lower impedance between electrodes and skin. Those requirements are usually acceptable, but not always welcome. Active electrode is an electrode that requires no skin preparation. It is possible with preamplifier placed very close to skin (inside the electrode). High dry skin impedance can be omitted by using amplifier with very high input impedance. Another reason to use active electrodes is safety. Because the dry skin-electrode impedance is very high (a few mega ohms) then the isolation barrier is much higher and a chance for an electrocution is much smaller comparing to passive electrodes.

3.6 Noise and Factors Affecting EMG Signal

EMG signal is affected by various factors.

- 1) Skin impedance – It can be lowered by using a conductive gel.
- 2) Electrode placement – It is the most important factors must be taken in to account while acquiring an EMG signal. Electrode must be placed at muscle of interest. Otherwise signal that will be generated is related to other muscle. Electrode must be placed in middle of muscle and also parallel to the muscle fibres. Inner electrode distance is also a factor. It should be between 10-30 mm [18].
- 3) Electrical noise – There are various types of electrical noise around in environment. Like all electrical instruments produce noise. It can be eliminated by using better quality of component. Electromagnetic noise is also a source of noise, but is impossible to avoid it.
- 4) Motion artifact – When motion artifact is introduced to the system, the information is lost. Motion artifact causes irregularities in the data. There are two main sources for motion artifact that are electrode interface and electrode cable. Motion artifact can be reduced by proper design of the electronic circuitry and set-up [25].

The quality of signal can be improved by following ways:

- 1) The signal-to-noise ratio should contain the highest amount of information from EMG signal as possible and minimum amount of noise contamination.

- 2) The distortion of EMG signal must be as minimal as possible with no unnecessary filtering and distortion of signal peaks and notch filters are not recommended as they destroys signal's information also.

3.7 Signal Conditioning

Advent of modern electronics and the process of differential amplification have enabled the measurement of EMG signals of low noise and high signal fidelity (i.e. high signal to noise ratio). With differential amplification, it is now possible to measure the full effective bandwidth of the EMG signal. Typical bandpass frequency ranges are from between 10 and 20Hz (high pass filtering) to between 500 and 1000Hz (low-pass filtering). High-pass filtering is necessary because movement artifacts are comprised of low frequency components (typically <10Hz). Low pass filtering is desirable to remove high-frequency components to avoid signal aliasing. In the past, it was common to remove power-line (A/C) noise components (i.e. either 50 or 60Hz) by using a sharp notch filter. There are problems with notch filtering because EMG has large signal contributions at these and neighbouring frequencies. The result of notch filtering is the loss of important EMG signal information, so notch filtering should be avoided as a general rule [18].

3.8 EMG Signal Analysis Methods

Recent advancements in techniques of signal processing and signal analysis have increased the importance of SEMG. Various mathematical tools and software made the understanding of SEMG signal more accurate. Mathematical models include time-frequency approaches, Fourier transform, Wigner-Ville Distribution (WVD), statistical measures and higher-order statistics. AI approaches toward signal recognition include Artificial Neural Networks (ANN), dynamic recurrent neural networks (DRNN) and fuzzy logic system. Wavelet analysis time frequency approach is suited to non stationary signal like SEMG. Genetic Algorithm (GA) has also been applied in evolvable hardware chip for the mapping of EMG inputs to desired hand actions. To employ these mathematic s tools various software are available in market, like Matlab and LabVIEW. All these techniques has made the practical implementation of EMG possible. The biggest example for this is the development of EMG based prosthetic limbs. They are much superior to other type of prosthetic limbs [1].

3.9 Human Jaw Anatomy

3.9.1 Jaw Bones

Human Jaw bones can be divided in two parts. First part is upper part is called Maxilla and second part which is lower jaw called Mandible. The other bone which form the part of human jaw and also the part of skull is called Temporal bone. The point where temporal bone and mandible meets is called Temporomandibularjoint. It is moveable joint. It allows movement and flexibility between two bones. The jaw joint allows movement between the mandible and the temporal bone. Muscles attached to the skull and jawbone makes the jaw bones to move as the mouth is opened and closed [26]. The Figure 3.2 shows the location of human jaw and skull bones.

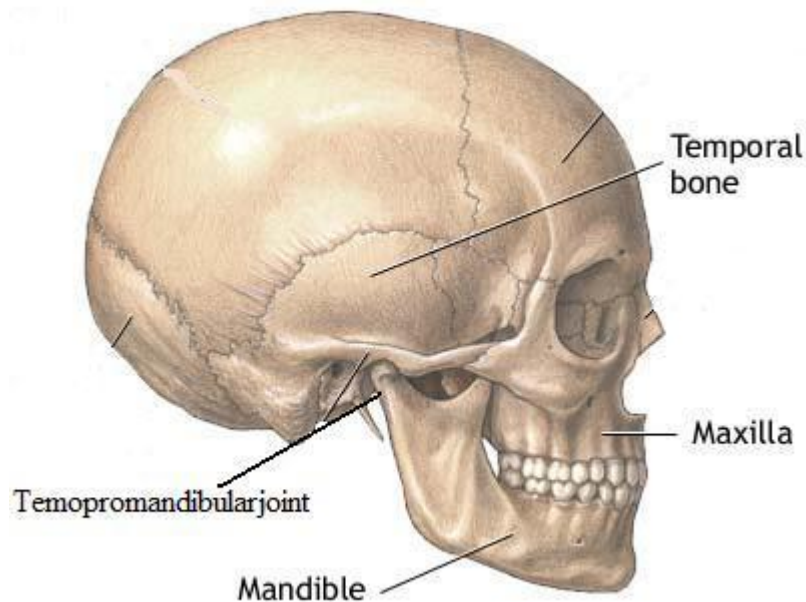


Figure 3.2 Human Skull and Jaw Bones [Online 1]

3.9.2 Muscles of Mastication

Mastication means chewing. The human masticatory system consists of a mandible which is able to move in relationship to the skull and is guided by two temporomandibular joints through contractions of masticatory muscles [27]. There are four muscles of mastication, that are temporalis, masseter, lateral pterygoid, medial pterygoid. But the temporalis and masseter muscles are mainly responsible for the movements of jaw for oral functions. Other reason is that these two muscles are located more or less superficially and other are more deeply like medial pterygoid. In this study only masseter

and temporalis muscle are studied. As they are easily located for SEMG recording [27]. Locations of muscles are shown in Figure 3.3.

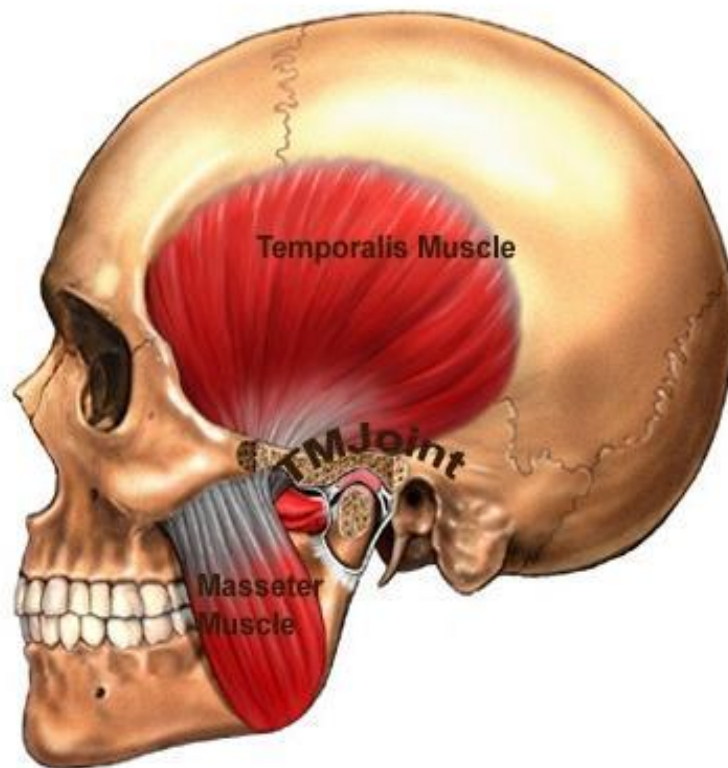


Figure 3.3 Human Mastication Muscles [Online 2]

1) Temporalis Muscle

As name suggests this muscle is located area between ear and eye as shown in figure 2. It can be felt whenever we do some movements in jaw. The part which is near to eye is called anterior temporalis muscle and part behind the ear is called posterior temporalis muscle. Its function is to elevate the mandible and sideways movements of jaw. It is the only muscle of mastication which has its attachment to the **TMJ** [27].

2) Masseter Muscle

It is one of the most powerful muscle in human body. It is located just above the curved path of mandible as shown in figure 2. It can also be located whenever we are doing normal oral functions. This muscle is thicker than temporalis muscle. Its function is to elevate and retraction of the mandible for crushing of food [27].

3.10 Human Neck Muscles

There are many muscles in human neck which are responsible for oral functionality. The other functions of neck muscles are movement of neck. The muscles related to human voice box are also situated in neck. But muscles that are related to swallowing are of interest in this study.

The swallowing is a complex process in which many muscles act in a coordinating way. But the Submental muscle is directly related to the swallowing process [22]. It is just situated under the chin. It can be felt easily by placing finger under the chin when swallowing takes place. It is in triangle shape, that's why the whole area is called as Submental Triangle. The Figure 3.4 shows where the submental muscle is situated.

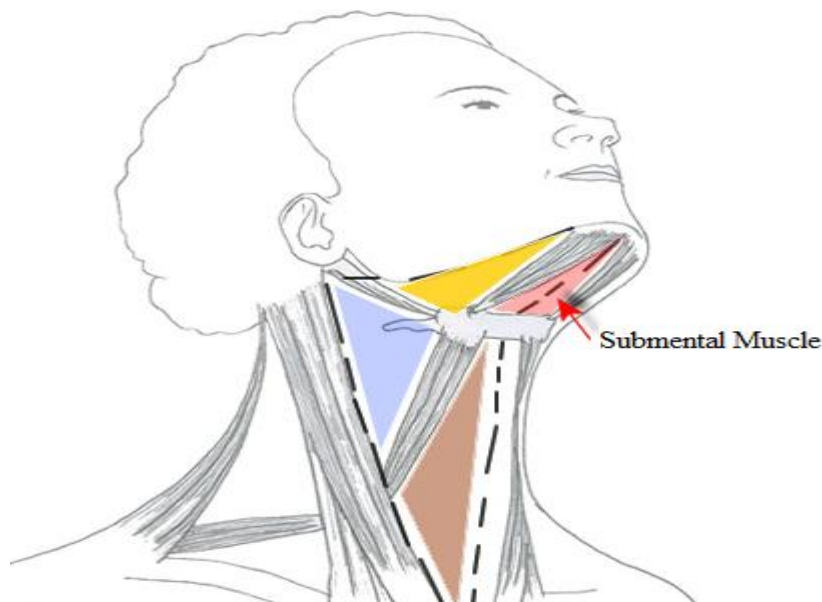


Figure 3.4 Submental Muscle [Online 3]

So in total three muscles from human jaw and neck were selected in this study. That are Masseter, Temporalis and Submental Muscles.

3.11 Usefulness of SEMG in Dentistry

SEMG in dentistry plays a very important role. All muscle related to jaw can be evaluated by SEMG. Before the development of EMG, the strain gauges were used to put inside the mouth of patient to evaluate his oral performance. Strain gauge gives the amount of pressure that was put by patient during oral activities. This was a very uncomfortable for patient. This method has various disadvantage which are listed below

- 1) Every time a new strain gauge was needed.
- 2) The cost of overall system becomes very high.
- 3) It was a painful process also as strain gauge.

EMG in dentistry is still not in use widely. By analyzing the EMG activity of a person one can evaluate the oral performance. The EMG in dentistry becomes more important when it comes to evaluate the performance or adaptability of person to various kind of artificial denture. If a person giving more EMG activity during a particular type of denture, it means he is facing problems to adapt to new denture. A low EMG activity is parameter of good oral condition [2].

The hyperactivity in jaw muscles can also lead to a permanent headache. Many other disorders related to jaw are caused by hyperactivity and overuse of muscles. EMG can efficiently measure these kinds of hyperactivities of jaw muscles [2].

Chapter 4

Material and Methodology

This chapter describes about various materials and methods that were use in this study. It describes how SEMG signal was picked from two jaw muscles and one neck muscle with various types of eating items. This chapter also describes how signal was acquired using LabVIEW and NI-DAQ card and also various parameters that were calculated for feature extraction of SEMG signal. This chapter describes how the actual work had been done.

4.1 Electrode

In this study the disposable surface electrodes were used. These electrodes are cheap, easily available, easy to use, hygienic and non reusable. These electrodes are only use for picking up the SEMG signal. The electrodes which are used in this study are shown in Figure 4.1.



Figure 4.1 Disposable Electrode

The gel which is required for lowering the skin impedance is contained in these electrodes. Thus some sort of skin cleaning is required before taking SEMG readings. Bipolar electrode configuration was used in this study. Inner electrode distance was kept as 1 inch. The ground electrode was placed on forehead.

4.1.1 Amplifier

The SEMG signal is order of millivolts. So for any of processing one must amplify it. The disposable electrodes are only use picking up the signal. These electrodes are attached to crocodile clips. These crocodile clips carry the SEMG signal to an amplifier circuit. The

amplifier was a two stage amplifier with total of gain 5000. The first stage was an instrumentation amplifier which provided gain of 5. The second stage was a simple non inverting amplifier which provides the gain of 1000. Thus total gain becomes 5000 [18]. The amplifier circuit was operating on 5 volts dual power supply.

4.2 LabVIEW

LabVIEW is the abbreviation for Laboratory Virtual Instrument Engineering Workbench. It is a powerful and flexible instrumentation and analysis software system developed by National Instruments. It is a highly productive development environment for creating custom applications that interact with real-world data or signals in fields such as science and engineering. It is system design software that provides users with the tools needed to create and deploy measurement and control systems through unprecedented hardware integration. It is much like various commercial C or BASIC developments systems. However, LabVIEW is different from those applications in one important aspect. While other programming system use text based languages to create a lines of code, LabVIEW uses a graphical language, G, to create a program in a flowchart like form called block diagram, eliminating a lot of the syntactical details. It relies on graphic symbols rather than textual language to describe programming actions [28].

It contains application specific libraries for data acquisition, GPIB and serial instrument control, data analysis, data storage and data presentation. Its library contains functions for signal generation, signal processing, filters, statistics, linear algebra, array arithmetic and near about each and every function that any instrumentation and analysis software should have. It includes conventional program development tools with which user can set break points, single step through the program, and animate the execution so you can observe the flow of data. There are some add on toolboxes also available in market for LabVIEW that have application specific purpose, like toolbox for wavelet analysis, toolbox for digital image processing etc. Because of its graphical nature, it is inherently a data presentation package. Output appears in any form in which user desires, like charts graphs arrays etc. In this study LabVIEW 2009 was used for SEMG signal acquisition and LabVIEW 2011 for SEMG data analysis.

4.2.1 Components of LabVIEW

A LabVIEW program is called VI. It stands for virtual instrumentation. Because of their appearance and operation imitate actual instruments. A VI has four main parts:

1. **Front Panel:** It is the interactive user interface of a VI, so named because it simulates the panel of a physical instrument. The front panel can contain knobs, push buttons, graphs and many other controls (user inputs) and indicators (program outputs). A user can use a mouse or keyboard to view the result produced by his VI [28]. The front Panel is shown in Figure 4.2.

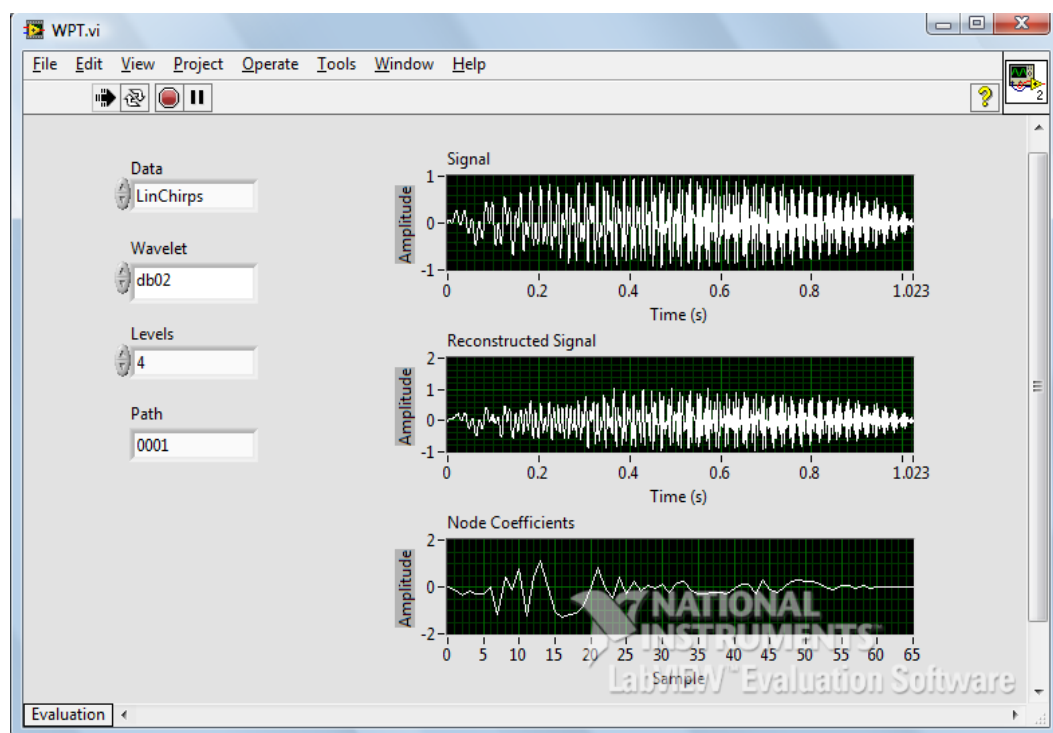


Figure 4.2 Front Panel

2. **Block Diagram:** It is the VI's source code, constructed in LabVIEW's graphical programming language; G. The block diagram is the actual executable program. The components of a block diagram, icons, represent lower level Vis, built-in functions, and program control structures. We can draw wires to connect the icons together, indicating the flow of data in the block diagram [28]. The block diagram is like the circuit diagram of an instrument which is behind the operating panel and which performs the actual functions. Simply it is analogous to human brain. The block diagram is shown in Figure 4.3.

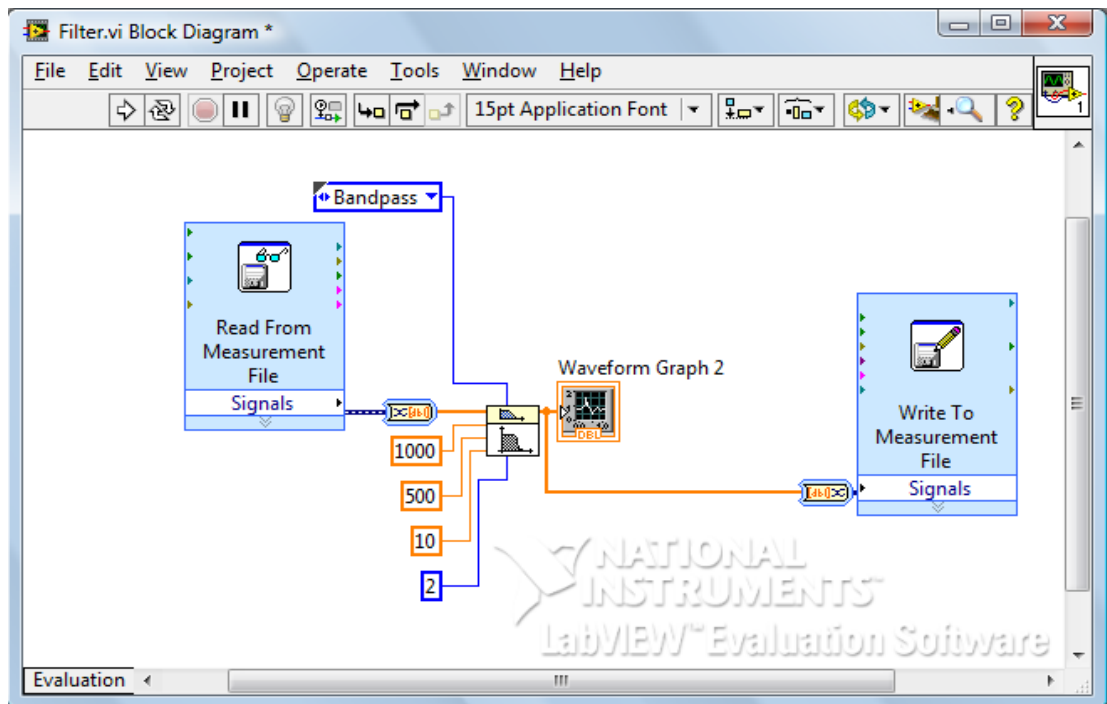


Figure 4.3 Block Diagram

3. Icons and Connectors of a VI: They allow other VI's to pass data to the VI. The icon represents a VI in the block diagram of another VI. The connector defines the inputs and outputs of the VI. It can use a VI as top level program, as subprogram within other programs, or even within other subprograms. A VI used with another VI, analogous to a subroutine, is called a subVI [28].

4. Node: A node is a program execution element. Nodes are analogous to statements, operators, functions, and subroutines in standard programming language. The arithmetic functions like division, add represents one type of node.

4.2.2 Data flow programming

In other text based programming language instructions are executed in the sequence in which they are written. Since LabVIEW is not a text-based language, its code cannot execute “line by line.” The principle that governs LabVIEW program execution is called data flow. While traditional execution flow is instruction driven, dataflow execution is data driven or data dependent. A node executes only when data arrives at all its input terminals; the node supplies data to all of its output terminals when it finishes executing; and the data passes immediately from source to sink, or destination, terminals [29].

4.3 NI-DAQ Card PCI - 6024E

Data acquisition means process of bringing the real world signals in to our measurement system like computer for processing, analysis, storage, presentation etc. This means we need a hardware which will do this task. In this work we are using National Instrument Corporation's data acquisition card PCI – 6024E for acquisition of SEMG signals. NI-DAQ also provide software driver which allow us to communicate between DAQ card LabVIEW. NI-DAQ is the robust driver software included with all National Instruments data acquisition and signal conditioning products. This easy-to-use software tightly integrates the full functionality of your DAQ hardware to LabVIEW, Lab Windows/CVI, and Measurement Studio for Visual basic. High-performance features include multi device synchronization, networked measurements, and DMA data management. Firstly we need to install software driver on to our system. This library includes functions for acquiring, generating data. LabVIEW can command DAQ card to read analog input signals (A/D conversion), generate analog output signals (D/A conversion), read and write signals, and manipulate the on board counters for frequency measurement, pulse generation, etc. The voltage data goes into the plug-in DAQ card in computer, which sends data into computer memory for storage, processing, or other manipulations [28].

The PCI-6024E features 16 channels of analog input, two channels of analog output, a 68-pin connector and eight lines of digital I/O. We are concerned only with the analog inputs of DAQ card. There are other functions also on this card, which include digital inputs, digital outputs, analog outputs, function generator, external triggering, dedicated port for thermocouple and transistor. It has a 12 bit successive approximation analog to digital converter. It has maximum sampling rate of 200000 samples/second.

A 68 pin connector is used to connect this DAQ card to computer system. This connector is also provided by National Instruments with this DAQ card. The DAQ card gets the operating power from this connector when it is connected to computer. There is no need of any external power for any kind of port of DAQ card for operation. The DAQ which we had used in this study is shown in Figure 4.3. The complete experimental setup is shown in Figure 4.4.



Figure 4.3 NI DAQ Card PCI-6024E

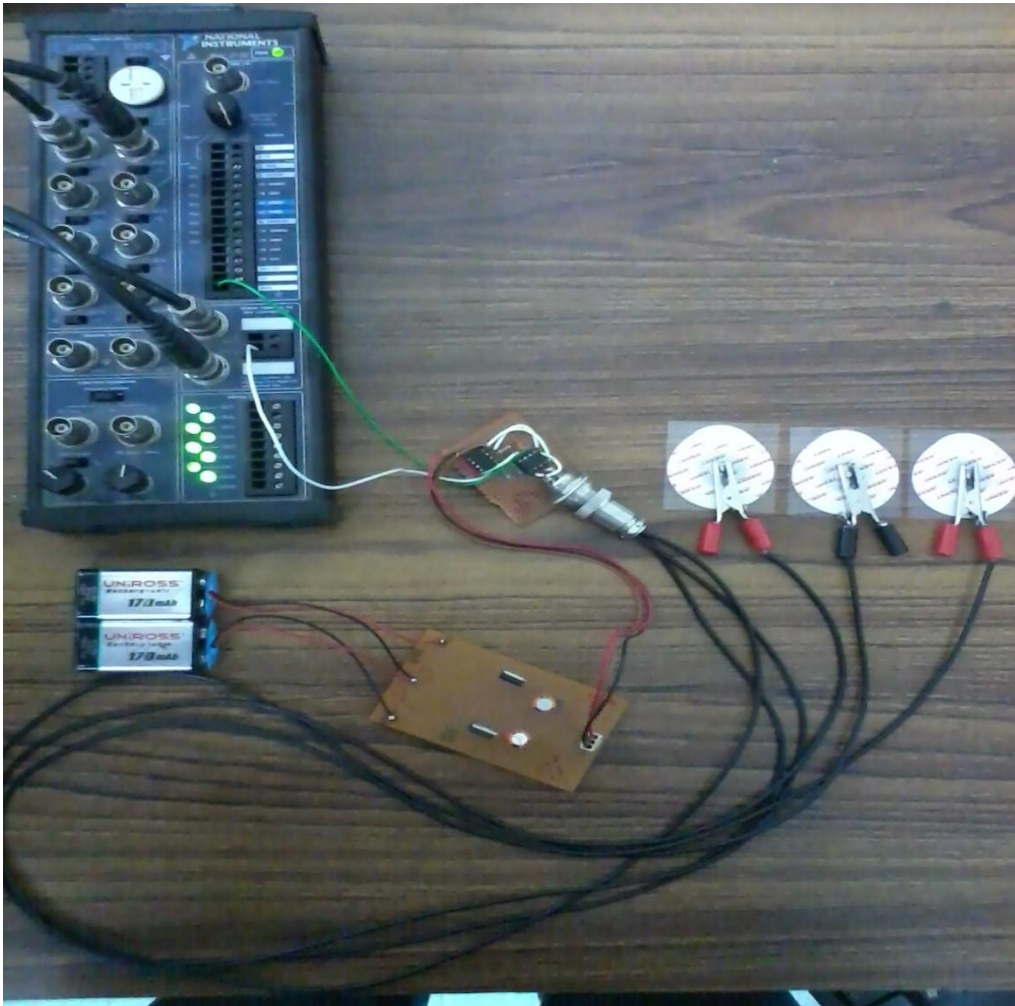


Figure 4.4 Complete Experimental Setup

4.4 Subject Selection

Five healthy males were selected for readings with a mean age of 25 approximately. Consent of all subjects was taken. All subjects had good oral conditions. They do not have any history of temporomandibular joint dysfunctioning and any other disorder like muscle pain, bruxism etc.

4.5 Jaw Muscles

In this study the two jaw muscles and one neck muscle that had been describe in Chapter 3 were selected for SEMG recording. In this study only right side of all subjects were considered. It means signals were acquired from three muscles that are Masseter, Temporalis and Submental muscle of right side of jaw. These muscles can easily located by palpation method. Subjects are asked to move their jaw up and down continuously. During this moment, by placing fingers one can easily identifies the position of muscle. The figure 4.5 gives the very fair idea where the muscles are.

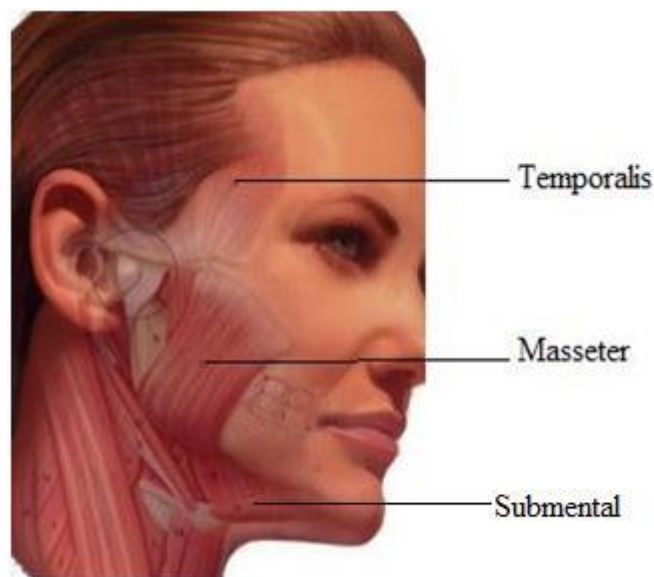


Figure 4.5 Locations of Jaw Muscles [Online 4]

When a subjected is asked to move jaw then the Masseter and Temporalis muscle show visible movement on skin and also these movements can be easily felt by using fingers. For Temporalis muscles there is some problem. As it's some part is above the ear which is covered by hairs. But we place our electrode on the area between eye and hair line of scalp, which is free from hair. This part of Temporalis muscle is called as anterior

temporalis muscle. For Masseter muscle electrode is placed at the centre of the muscle and also parallel to the muscle fibres [25]. For location of Submental muscle subject were asked to swallow his saliva. At this activity movement in Submental muscle can be felt easily, by placing fingers under the chin one can felt the Submental muscle. This muscle was hard to find as compared other two muscles, because there are many muscles located near to Submental muscle.

4.6 Conditions and Procedure for SEMG Signal Acquisition

Before starting signal acquisition process some sort of conditions were fixed which includes test food materials, precautions, duration of signal recording, some instructions for subjects etc. These conditions and procedure were fixed for every subject.

4.6.1 Food Items

Total of four food items were use as test food.

- 1) Water – The quantity of water was fixed to 150ml.
- 2) Banana – The subject was asked to bite banana according to his comfort.
- 3) Candy – An Alpenliebe candy product of Perfetti.
- 4) Chewing Gum - A Center Fresh chewing gum product of Perfetti.

4.6.2 SEMG Signal Acquisition Procedure

Subject was asked to sit on a chair in relaxed manner or position in which he felt comfortable. Each SEMG signal was recorded for duration of five seconds. Only the right side of jaw was selected for SEMG signal. All activities were done only using the right side of our mouth. Subjects were asked to chew the test food items only from right side of mouth. A break of three to five minutes break was taken before next recording.

The orders of activities were decided in a way that subject feel comfortable. It means he ate all the test food items normally. For example, lets we have two food items A and B. Food item A is more sweet than food item B. A person likes both the food items. But if same person ate food item A first and then food item B. It is a natural human tendency that he will not like the food item B as much as if takes the food item B alone. This condition can affect SEMG signal. This kind of studies had been reported in past that food items taste can also affect the SEMG signal [17]. So the test food items were

selected in manner that is suitable for everyone. The order in which the activities were performed is described below and also the reason why these activities were performed.

- 1) Rest Position: In this position subject was asked to keep their jaw closed so that teeth on maxilla and mandible do not meet each other. If teeth on both maxilla and mandible meet then subject will show the activity in Masseter and Temporalis muscle. The purpose of this reading was to evaluate the signal when jaw is at rest, without muscle activation in Masseter and Temporalis.
- 2) Water: Subject was asked to drink the fixed amount of water. The purpose of this activity was to evaluate the signal in swallowing water.
- 3) Maximum Force: The subject was asked to clench their teeth with full force as much as possible. The purpose of this reading was to evaluate the maximum force that can jaw muscle generate.
- 4) Candy: The candy was given to subject and he is asked to bite the candy as in his natural manner. This gives the idea about how much force was generated in biting a hard thing. We selected because they are least affected by environmental conditions like temperature and humidity etc. This gives the standardization in food items for every subject.
- 5) Banana: All readings were recorded for six seconds but this recording was done until the subject complete the eating and swallowing process of banana. When subjects indicated that he had done with banana then acquisition was stopped. The purpose of this reading was to see the difference between the SEMG signal of normal chewing and swallowing.
- 6) Chewing gum: First the subject was asked to chew the chewing gum until it softens. At this point we start recording of SEMG signal. This gives the idea about difference the SEMG signal of biting hard thing (Candy) and soft thing (chewing gum). This same case as of candy, chewing gum also gives standardization in food items.

The different activities were named differently as shown below.

- 1) A – Rest
- 2) B – Drinking

- 3) C – Banana
- 4) D – Chewing Gum
- 5) E – Candy
- 6) F – Maximum Force

This was done just to simplify the parameters which we are calculating and for the better representation of our results.

4.6.3 Precautions Taken While Acquiring Signal

- 1) During whole experiment the unwanted electrical appliances were kept off or kept away from experimental setup to avoid the electromagnetic noise in signal.
- 2) Means of wireless communication such as mobile phones are kept away or switched off during signal acquisition.
- 3) Every subject was asked to keep their eye closed and stable to avoid noise caused by occlusal movement. As the temporalis muscle is situated near to eye and movement in eye will cause artefact [4].
- 4) Subjects were asked not to move their head, this cause wires to move which are connected to electrode. The movements of wires are also the contributors of noise in signal [18].

4.7 Acquisition of SEMG Signal with LabVIEW

The SEMG signals were taken from three muscles. As only two channels was available, so three combinations of muscles was made to acquire signals. The SEMG signals that were fed to DAQ card are the output of amplifiers. The DAQ card was connected to our computer on which LabVIEW was installed. The sampling rate was set as 1024 samples/second, to avoid the aliasing of the signal. The signal was saved in to TDMS type of measurement file. It is a kind of binary file that can be directly open in MS-Excel. TDMS file also require less disk space as compare to other formats. This type of file is also very efficient when it comes to processing on to our system. Figure [4.6] shows the block diagram code for signal acquisition and Figure [4.7] shows front panel for the same. The value of sampling rate, configuration of channels, buffer size, maximum and minimum value, location where data will be stored and in which form was configured in this code of LabVIEW.

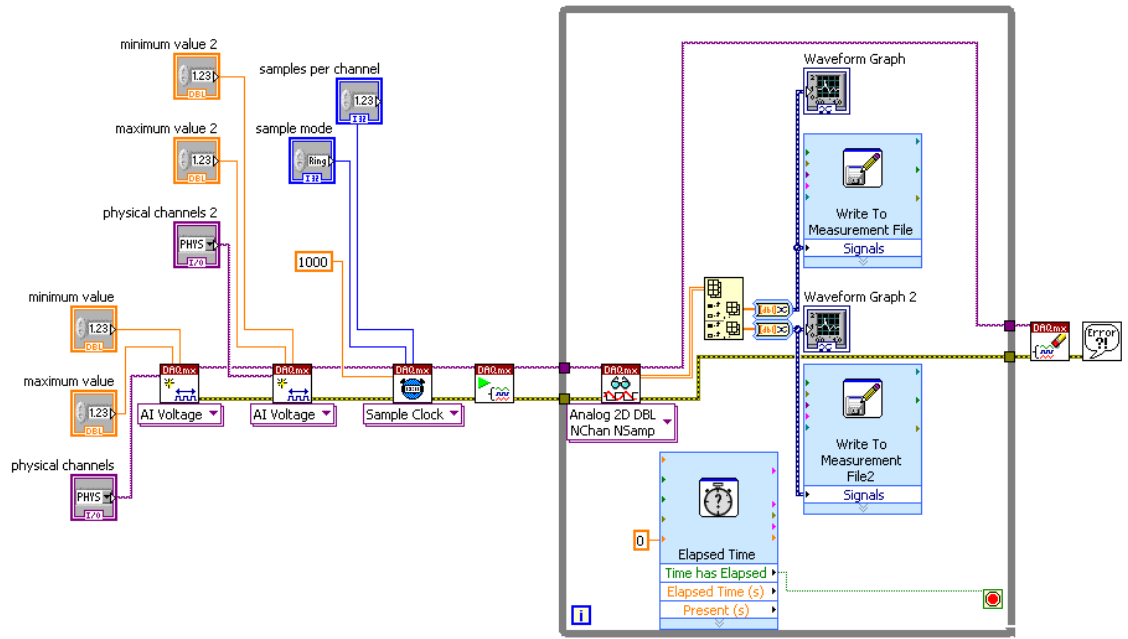


Figure [4.6] Block diagram for Signal Acquisition using LabVIEW

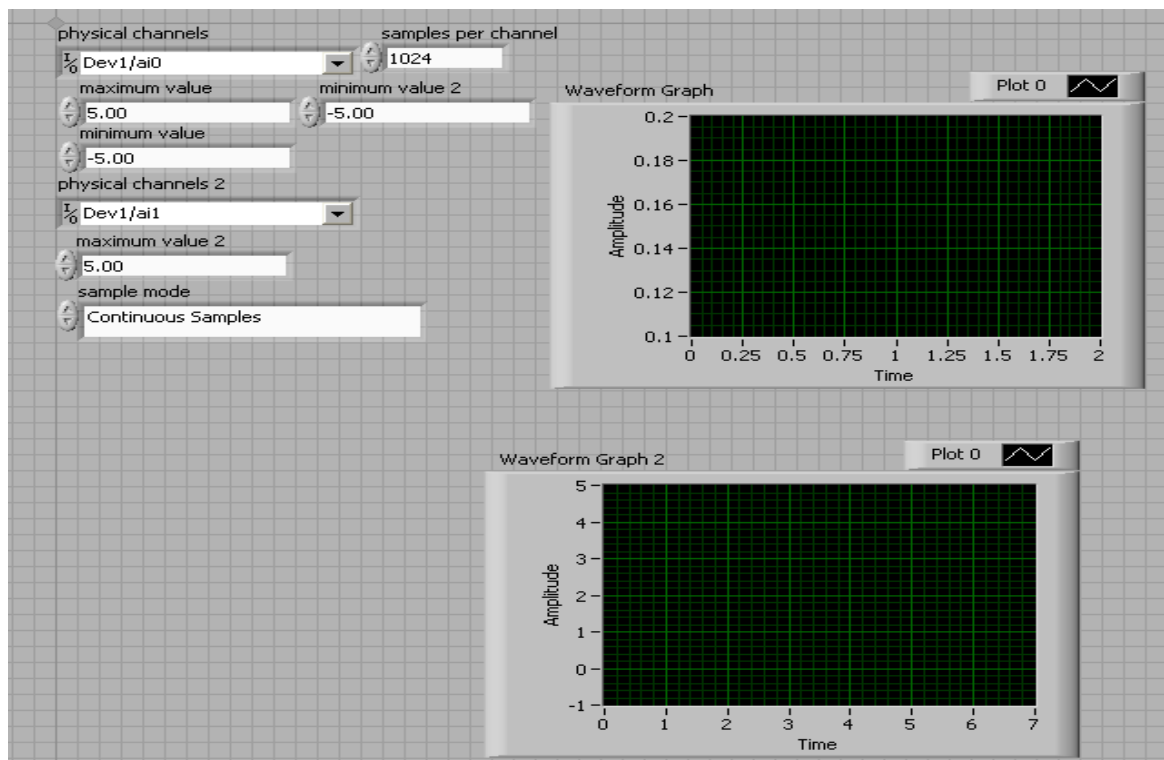


Figure [4.7] Front Panel for Signal Acquisition using LabVIEW

4.8 SEMG Signal Conditioning

After SEMG signal is acquired and saved in TDMS file. Then this signal was band pass filtered for 10Hz to 500 Hz in LabVIEW. The butterworth 2nd order filter was chosen for this purpose [18]. The maximum frequency content in a SEMG signal is up to the 500 Hz. Above 500 Hz signal is not of use. Lower limit 10 Hz was chosen because, the frequency of artifacts was below 10 Hz. Thus by high pass filtering by 10 Hz removes the all artifacts. Direct block of this filter is available in library of LabVIEW. Then this filtered was saved to another measurement file that is TDMS format.

4.9 Parameters Calculated

After the signal filtering various parameters were calculated for feature extraction. Significance of all features was described in this section

4.9.1 Root Mean Square

It is known as RMS value. It is the quadratic mean of the value of samples of a discrete signal. The formula for RMS is shown in Equation 4.1

$$RMS = \sqrt{\frac{1}{N} \sum_{n=1}^N x_n^2} \quad (4.1)$$

N = Number of samples in signal

X_n = Value of Sample at instant n

It is the one of the most important parameter to extract the features of SEMG signal. One can say that it is the actual value of signal. It measures the strength of the signal; this means it has a clear physical meaning. It is the most appropriate parameter to quantify the SEMG signal. It is most suited to a signal which has value fluctuating about the zero line. Means the signal contains the values that positive and negative. Thus it is applicable to SEMG signal, which is a random signal. A direct block is available in LabVIEW to calculate RMS.

4.9.2 Mean Absolute Value

MAV is abbreviated as Mean Absolute Value. Equation 4.2 shows the MAV.

$$MAV = \frac{1}{N} \sum_{n=1}^N |x_n| \quad (4.2)$$

x_n = Value of Sample at instant n

N = Number of samples in signal

As name suggests it is the mean of absolute value. It means first the absolute value of a digital signal at each instant is taken and then its mean is calculated. It is also an important parameter to quantify the SEMG signal. It is like that a mirror is placed at the horizontal axis of a signal which just reflects back the negative value of signal. It gives the mean absolute value of signal.

4.9.3 Power Spectrum

Power spectrum shows the variation in the energy of a signal as a function of frequency. It shows that at which frequency signals are dominant and how much. It is a qualitative analysis, in which user can tell about the dominant frequency contents in signal. It is computed by the auto correlation of signal. Its direct block is available in LabVIEW. In figure on X-Axis the frequency contents and on Y-axis the power of that frequency content in the signal.

4.9.4 Simple Square Integral

Basically it uses the energy of a signal to define it. It is a summation of square values of the EMG signal amplitude. Generally, this parameter is defined as an energy index, which can be expressed as in Equation 4.3

$$SSI = \sum_{i=1}^n x_i^2 \quad (4.3)$$

x_i = Value of Sample at instant n

n = Number of samples in signal

The main advantage of this feature is that it increases the scale. Means the difference between minimum and maximum value is large as compared to other parameters. It easily differentiates between SEMG activities which are separated by small value. Like in this study the force put in chewing gum chewing is just slightly greater than banana chewing.

4.9.5 Variance of EMG

It is also known as VAR. It is another power index. Variance is defined as an average of square values of the deviation of that variable; however, mean value of EMG signal is close to zero. It is better parameter than mean or average value of EMG signal. It is calculated as shown in Equation 4.4.

$$\text{VAR} = \sum_{i=0}^n (x_i - \bar{x})^2 \quad (4.4)$$

x_i = Value of Sample at instant n

n = Number of samples in signal

Results and Discussions

SEMG signals were acquired from five subjects for six different activities that were rest, drinking, banana chewing, chewing gum chewing, candy chewing and maximum force from three muscles. Results were obtained from the various parameters and fed to the SPSS software to perform the multivariate statistical analysis. The values of all parameters calculated that were described in section 4.9 and tabulated in Table 1 for subject 1, Table 2 for subject2, Table 3 for subject 3 respectively.

Table 1: Values of All Parameters for Subject 1

Muscle	Activity	RMS	MAV	SSI	VAR
Temporalis	A	0.035	0.027	6.536	0.0012
Temporalis	B	0.052	0.0411	14.25	0.0027
Temporalis	C	0.134	0.086	92.075	0.017
Temporalis	D	0.167	0.096	141.6	0.027
Temporalis	E	0.245	0.126	307.69	0.06
Temporalis	F	0.578	0.435	1708.41	0.334
Masseter	A	0.036	0.027	6.689	0.0013
Masseter	B	0.042	0.031	9.277	0.0018
Masseter	C	0.119	0.069	72.995	0.014
Masseter	D	0.141	0.071	102.7	0.02
Masseter	E	0.169	0.123	147	0.028
Masseter	F	0.352	0.263	634.12	0.124
Submental	A	0.05	0.038	13.083	0.0025
Submental	B	0.22	0.177	248.13	0.048
Submental	C	0.076	0.0592	29.732	0.0059
Submental	D	0.0746	0.0556	28.536	0.0056
Submental	E	0.099	0.074	50.92	0.009
Submental	F	0.06	0.048	21.66	0.004

Table 2: Values of All Parameters for Subject 2

Muscle	Activity	RMS	MAV	SSI	VAR
Temporalis	A	0.078	0.032	31.03	0.0058
Temporalis	B	0.11	0.055	58.54	0.006
Temporalis	C	0.242	0.12	300.84	0.0122
Temporalis	D	0.289	0.139	426.81	0.083
Temporalis	E	0.36	0.186	664.11	0.13
Temporalis	F	0.449	0.339	1033.2	0.201
Masseter	A	0.037	0.027	7.022	0.001
Masseter	B	0.045	0.033	10.416	0.002
Masseter	C	0.16	0.084	146.58	0.028
Masseter	D	0.17	0.093	155.12	0.03
Masseter	E	0.35	0.2	629.79	0.123
Masseter	F	0.36	0.186	664.11	0.13
Submental	A	0.036	0.025	6.784	0.001
Submental	B	0.101	0.067	53.0939	0.01
Submental	C	0.06	0.048	21.66	0.004
Submental	D	0.062	0.046	20.193	0.003
Submental	E	0.068	0.049	23.91	0.005
Submental	F	0.063	0.047	20.5	0.004

Table 3: Values of All Parameters for Subject 3

Muscle	Activity	RMS	MAV	SSI	VAR
Temporalis	A	0.037	0.028	7.229	0.0014
Temporalis	B	0.051	0.038	13.67	0.002
Temporalis	C	0.191	0.101	186.154	0.036
Temporalis	D	0.345	0.16	611.814	0.1196
Temporalis	E	0.408	0.26	852.89	0.166
Temporalis	F	0.567	0.442	1649.53	0.321
Masseter	A	0.028	0.0216	4.28	0.0008
Masseter	B	0.04	0.028	8.46	0.001
Masseter	C	0.149	0.078	113.74	0.022
Masseter	D	0.318	0.129	520.02	0.101
Masseter	E	0.385	0.211	758.88	0.148
Masseter	F	0.554	0.404	1575.5	0.307
Submental	A	0.0327	0.024	5.49	0.001
Submental	B	0.099	0.07	51.085	0.009
Submental	C	0.093	0.0693	45.13	0.008
Submental	D	0.0979	0.0729	49.16	0.0096
Submental	E	0.101	0.073	52.58	0.01
Submental	F	0.062	0.048	20.09	0.0039

5.1 Root Mean Square (RMS)

At different task the different muscles showed the different activity. Figure 5.1 shows the plot of RMS values of subject 1 at different activities. Figure 5.2 shows the plot of RMS for subject 2. Figure 5.3 shows the plot of RMS for subject 3.

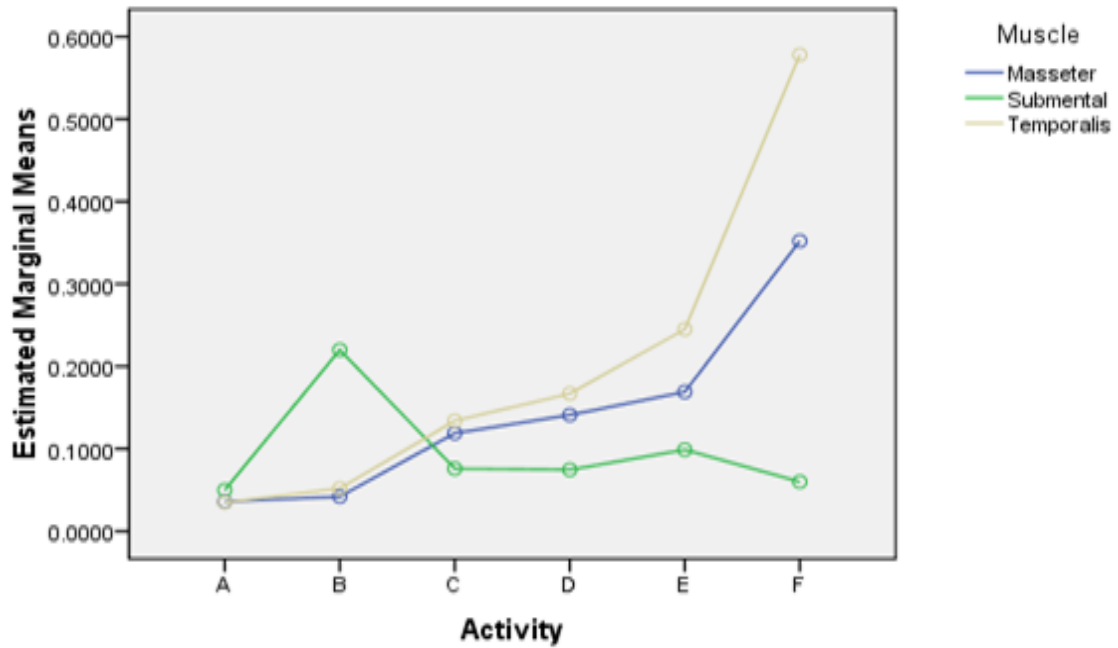


Figure 5.1 Plot of RMS for Subject 1

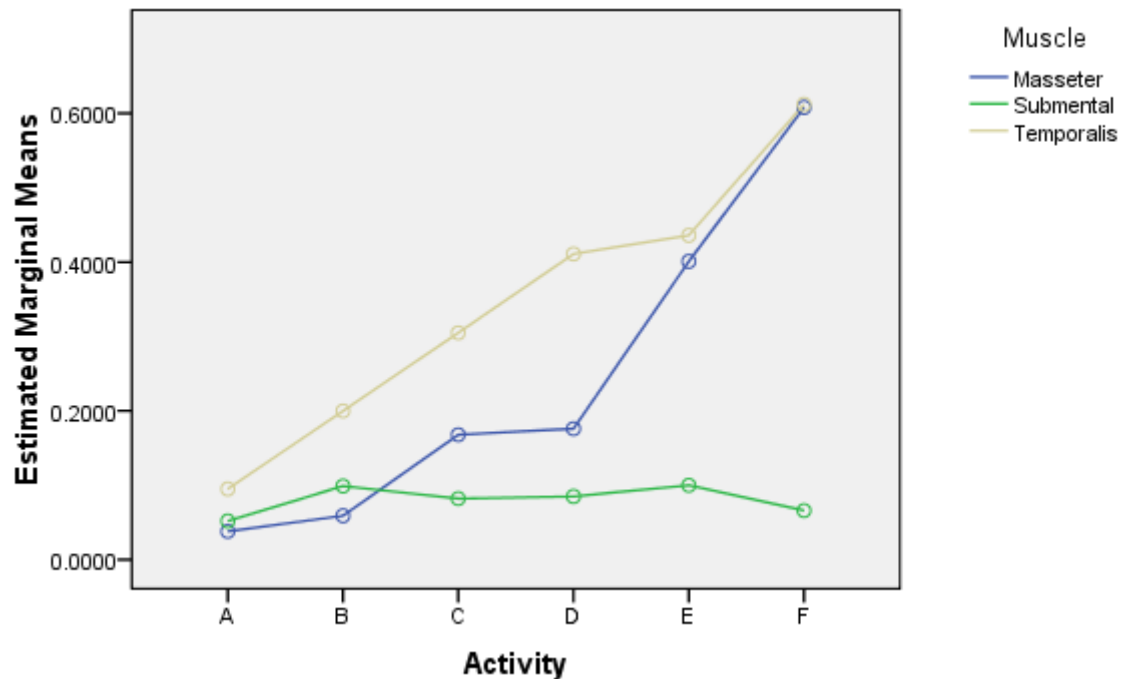


Figure 5.2 Plot of RMS for Subject 2

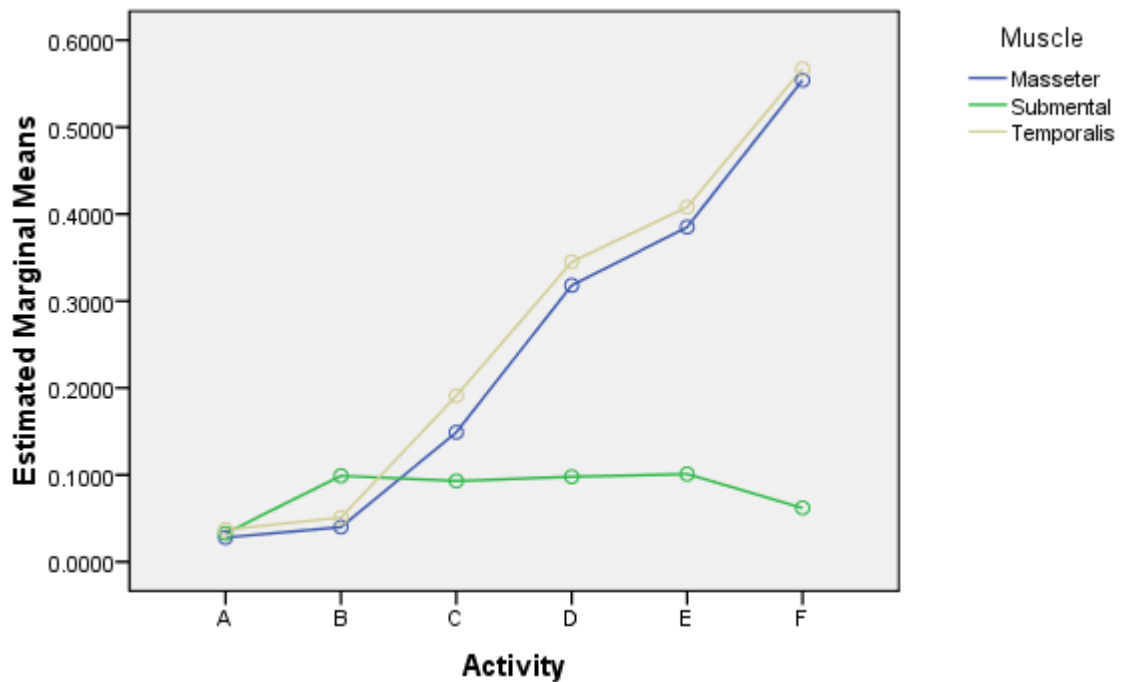


Figure 5.3 Plot of RMS for Subject 3

The value of RMS of SEMG signal from three subjects shows that the maximum force has the maximum value of RMS in temporalis muscle and in masseter Muscle. But the submental muscle has the maximum activity in water drinking. Whereas in drinking the values of masseter and temporalis muscle has the marginal increase in value from rest position. This suggests that in swallowing or drinking the submental muscle plays the major role. This is because the masseter and temporalis muscle mainly involved in the activities related to movement of jaw. But in drinking the movement of jaw is minimum and at that time the submental muscle activates. Submental muscle also show activity in other chewing activities. The SEMG of submental muscle varies from subject to subject. But when it comes to maximum force the submental muscle, the activity of submental muscle drops. This shows that submental muscle does play a role in jaw movement, but is less as compared to other two muscles. Submental muscle shows less activity when it comes to static activity like maximum force. The reason for this is there is no jaw movement in maximum force.

When we look the two jaw elevators muscle that are masseter and temporalis the show increase in SEMG as the hardness of food is increasing. But the temporalis muscle shows more RMS value as compared to masseter. The value of temporalis muscle is more than masseter muscle in every activity. But they shows the same pattern of increase in activity as the hardness of food increases.

5.2 Mean Absolute Value (MAV)

At different task the different muscles showed the different activity. Figure 5.4 shows the plot of MAV values of subject 1 at different activities. Figure 5.5 shows the plot of MAV for subject 2. Figure 5.6 shows the plot of MAV for subject 3.

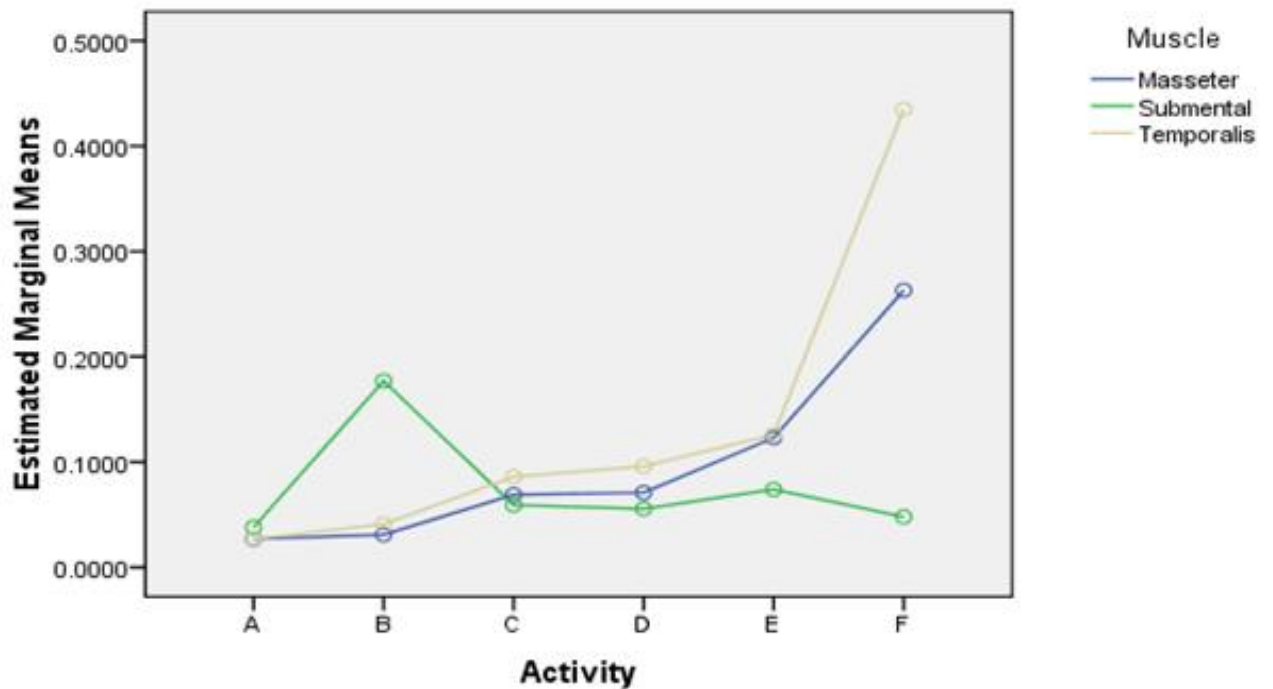


Figure 5.4 Plot of MAV for Subject 1 of all Three Muscles

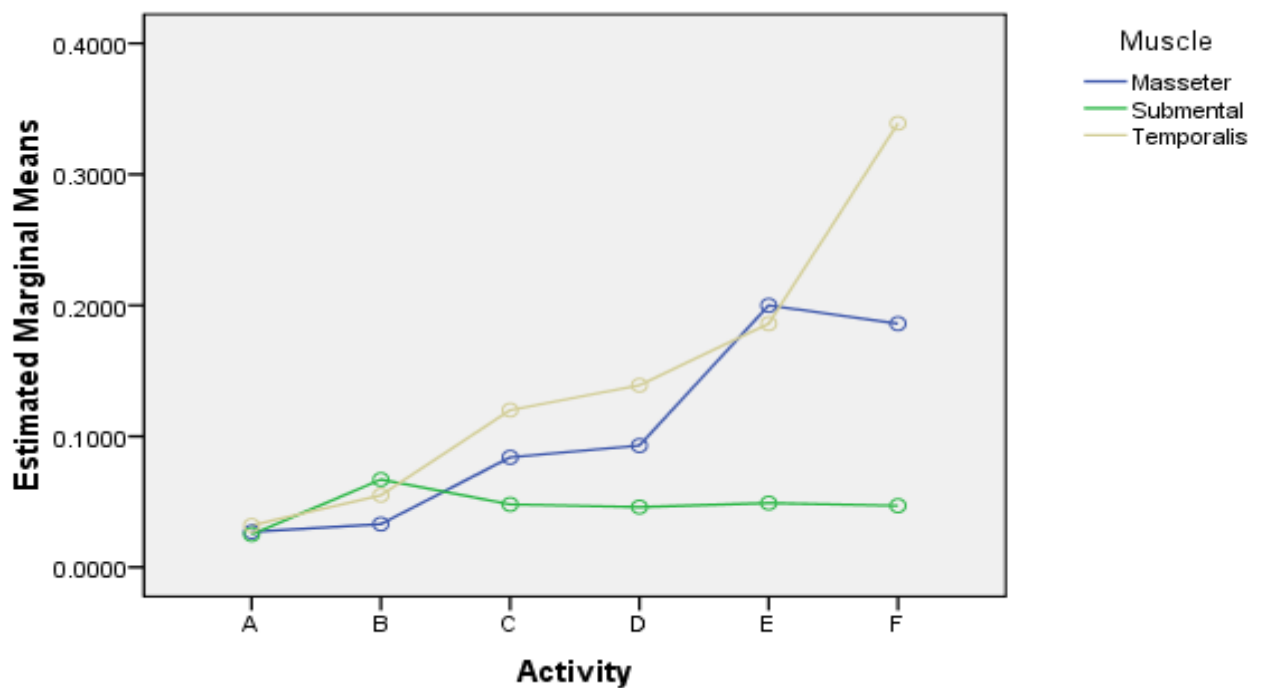


Figure 5.5 Plot of MAV for Subject 2 of all three muscles

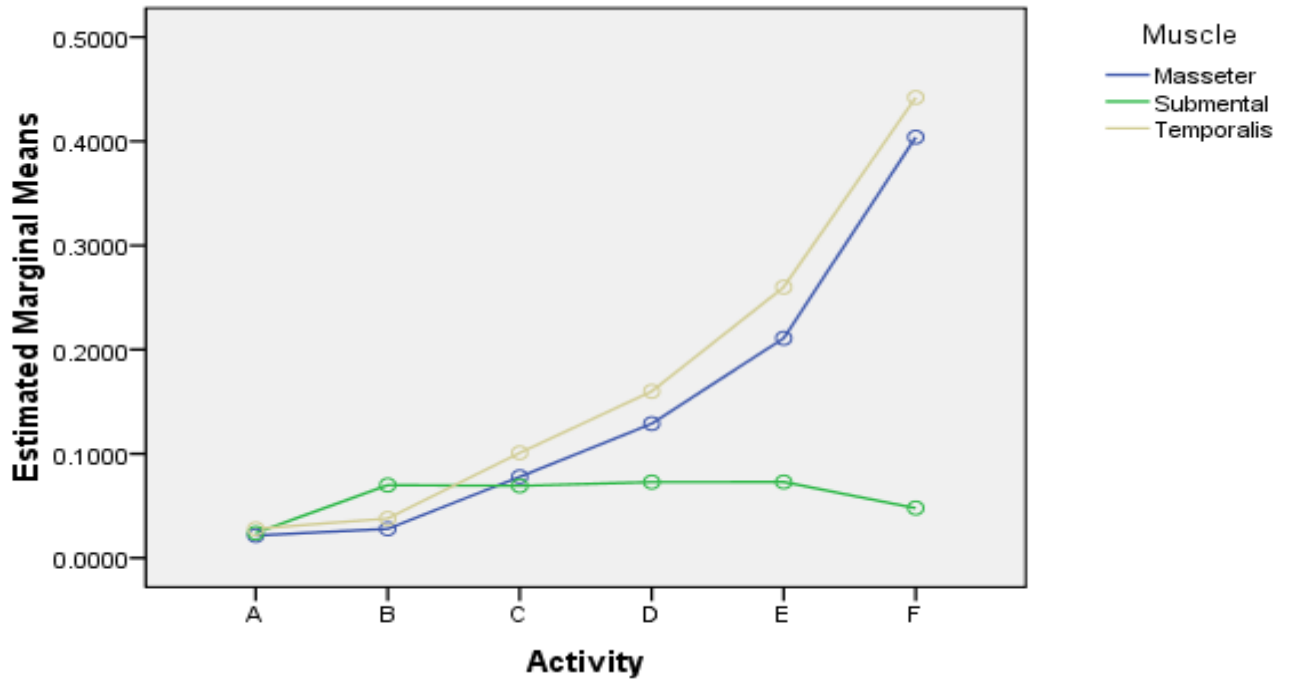


Figure 5.6 Plot of MAV for Subject 3 of all Three Muscles

The plots for MAV for three subjects depicts that the MAV value also provide good contrast between the activities for different muscles. The MAV value for submental muscle was the highest in water drinking. The submental also shows low activity in maximum force than other activities. It also shows better distinction in rest and water drinking activity in submental muscle. The temporalis muscle showed the maximum activity. But in subject 1 and subject 2 it shows that the value of masseter is more than temporalis muscle in activity E. Only this reading is not in consent with the RMS readings, while other readings are in consent with the RMS value.

The range of MAV is smaller as compared to the RMS value. But it is as good as the RMS value. The value of MAV is also increasing as the hardness of food item was increasing for the masseter and temporalis muscle. The advantage of this parameter is that there is no need of rectified EMG before the feature extraction process.

5.3 Simple Square Integral (SSI)

The plots for SSI for three subjects were below. Figure 5.7 shows the plot of SSI for subject1 for all the three muscles. Figure 5.8 shows the plot of SSI for subject 2 for all the three muscles. Figure 5.9 shows the plot of SSI for subjects 3 for all three muscles.

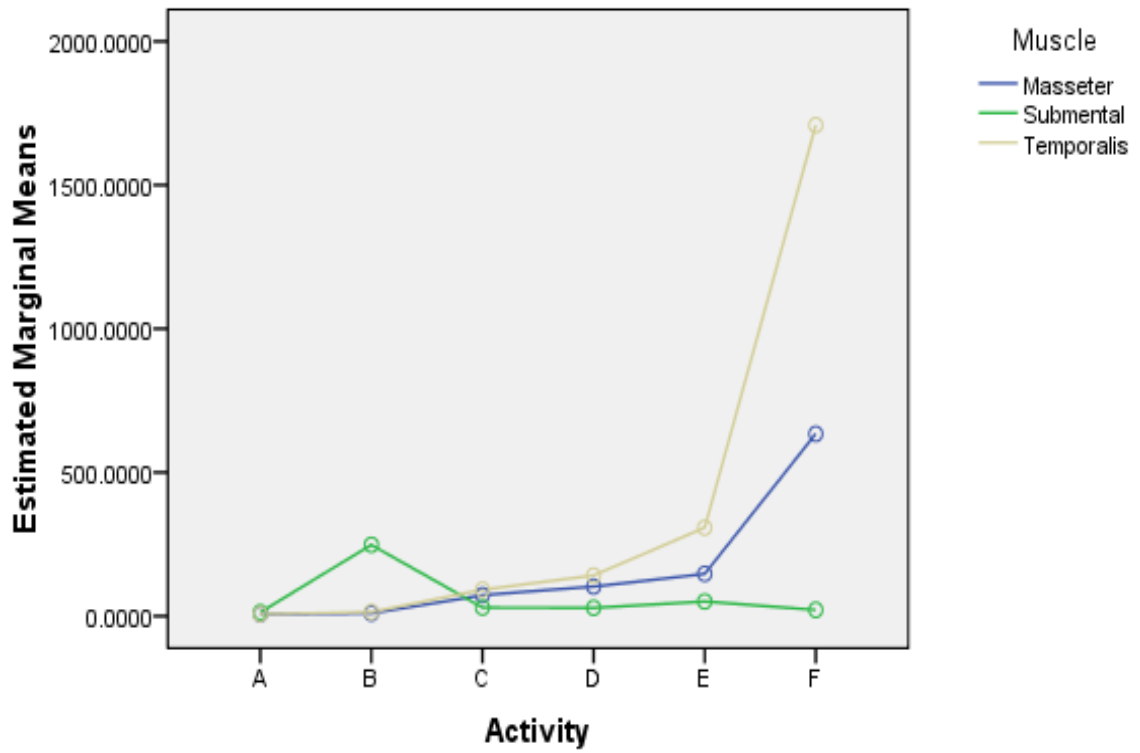


Figure 5.7 Plot of SSI for Subject 1 of all Three Muscles

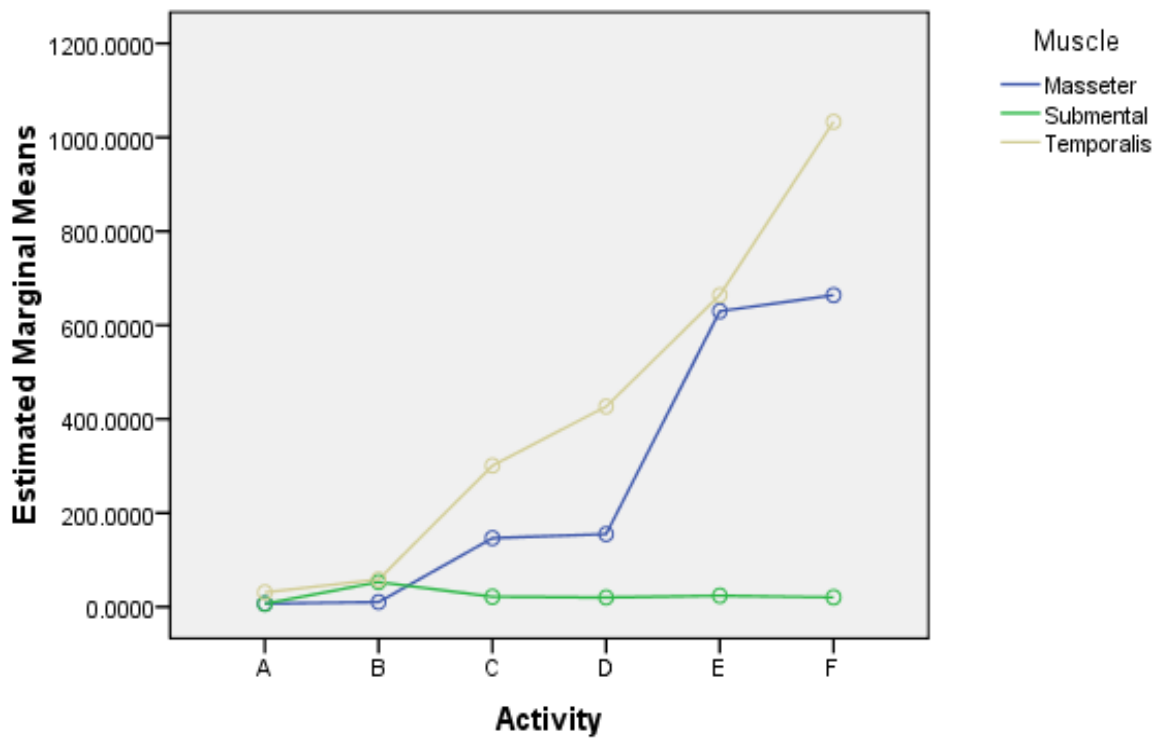


Figure 5.8 Plot of SSI for Subject 2 of all Three Muscles

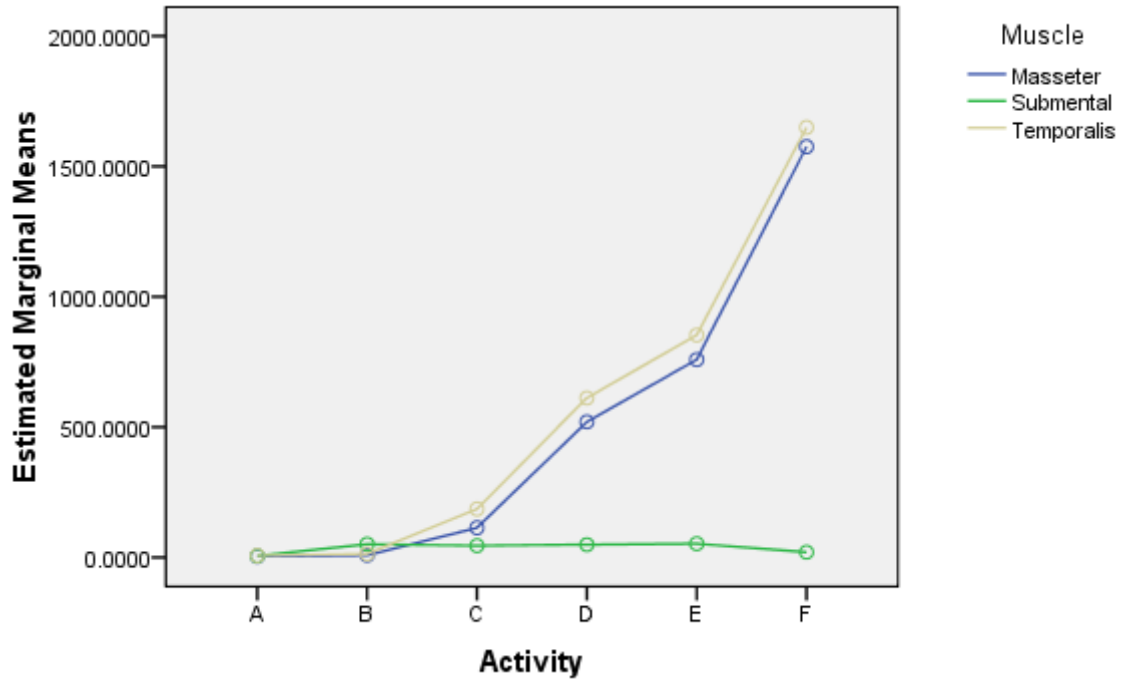


Figure 5.9 Plot of SSI for Subject 3 of all Three Muscles

The value of SSI is increasing with increase in force put by subjects in masseter and temporalis muscle. The plots shows that there is marginal increase in both the muscle in activity B as compared to activity A. But all other activities showed the good contrast between the SEMG value of both the muscle. This parameter has the highest range. The maximum value is 1708.64. The scale was increased up to the great extent.

When submental muscle was analyzed only subject 1 showed the good contrast between activity A and activity B. It has the highest value for activity B. Other two subjects also showed good variations but they are less as compared to subject 1. The SSI value of submental muscle is low in maximum force as compared to other chewing activity.

The SSI is also a useful parameter. It is most valuable the scale is to be stretched. Means the difference between highest activity and lowest activity is large. It is also useful in differentiating activities which are very closely separated. Like in this study the difference between activity C and activity D. But in this study the maximum value is 1708, that's why the submental muscle shows lower contrast between all the activities as compared to other parameters. Overall SSI also provides good information, as the scale was increased. But the disadvantage of this parameter is that if low scale values are plotted with high scale values then contrast in low scale values will be less.

5.4 Variance of EMG (VAR)

At different task the different muscles showed the different activity. Figure 5.10 shows the plot of RMS values of subject 1 at different activities. Figure 5.11 shows the plot of RMS for subject 2. Figure 5.12 shows the plot of RMS for subject 3.

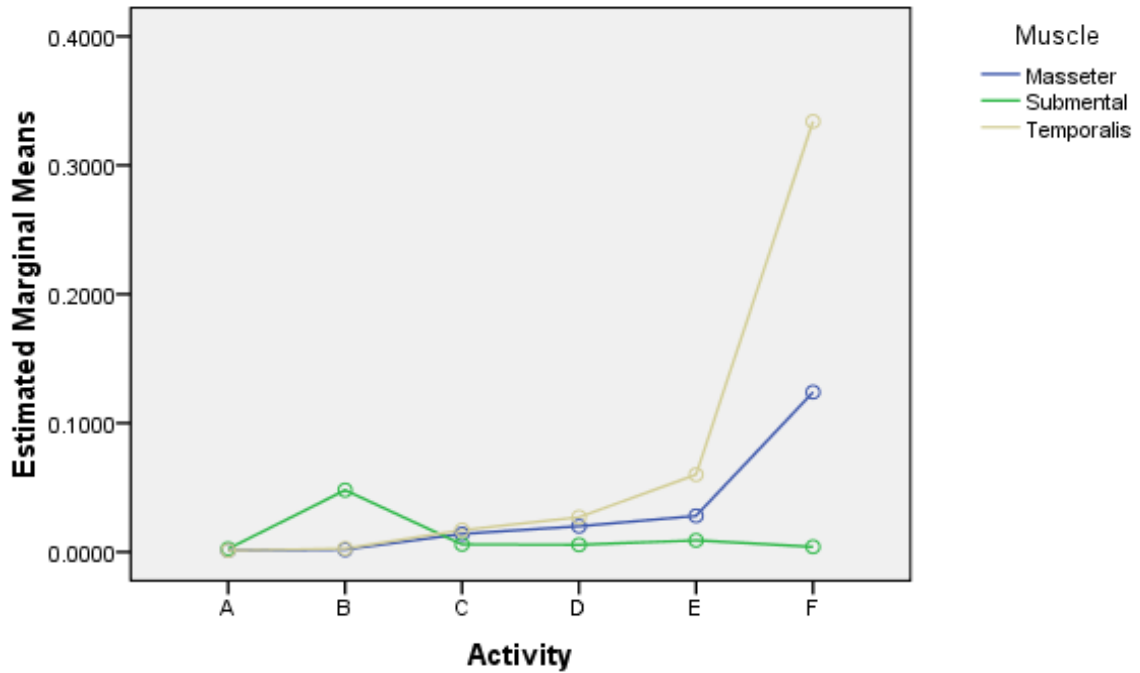


Figure 5.10 Value of VAR for Subject 1 of all Three Muscles

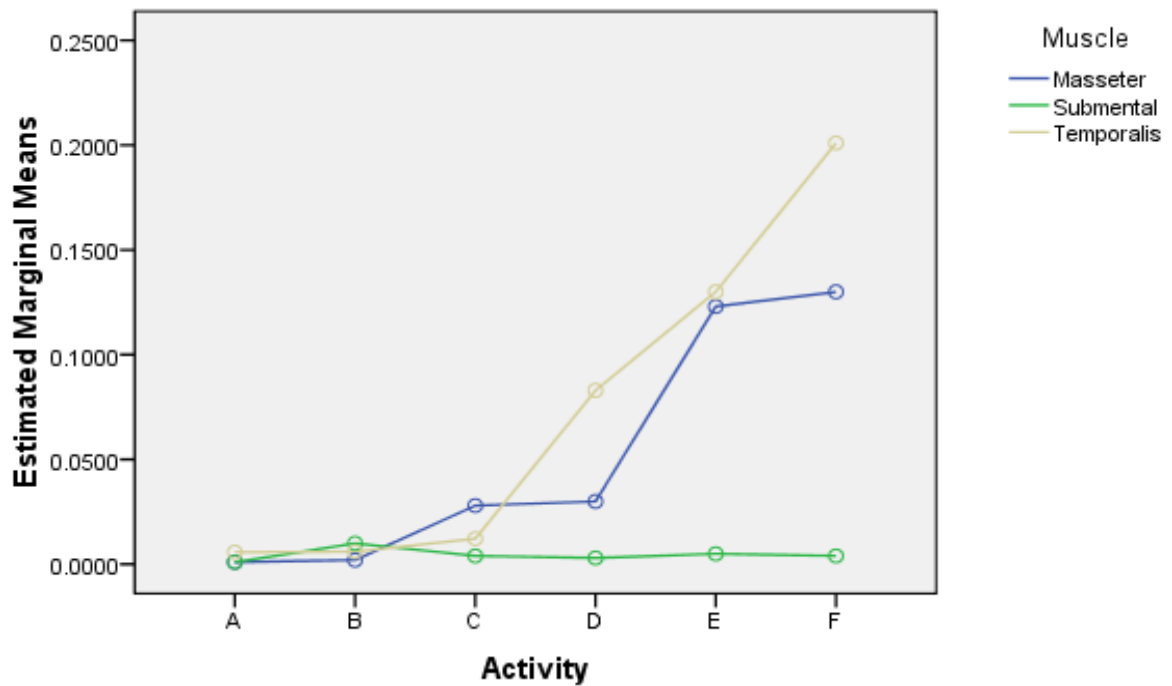


Figure 5.11 Value of VAR for Subject 2 of all Three Muscles

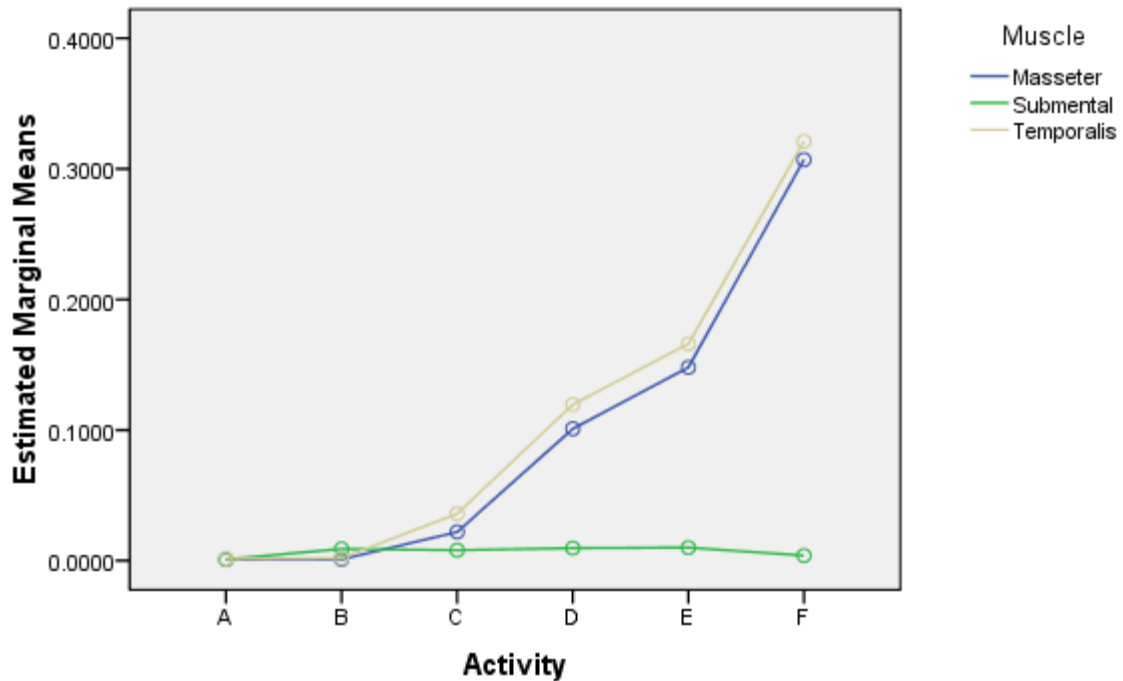


Figure 5.12 Value of VAR for Subject 3 of all Three Muscles

The variance has the lowest scale in all the four features. The value of VAR of SEMG signal from three subjects shows that the maximum force has the maximum value of VAR in temporalis muscle and in masseter Muscle. But the submental muscle has the maximum activity in water drinking. Whereas in drinking the values of masseter and temporalis muscle has the marginal increase in value from rest position. Submental muscle also show activity in other chewing activities. But when it comes to maximum force the submental muscle, the activity of submental muscle drops.

The difference between the highest value of temporalis and masseter muscle is more in subject 1 and subject 2. But in subject 3 the difference is less as compared to subject 1 and subject 2. Subject 3 also showed more uniform increase in value of masseter and temporal muscle.

Overall, the scale is decreased but still the VAR was able to differentiate between the different activities.

5.5 Power Spectrum

Power spectrum shows the variation in the energy of a signal as a function of frequency. It shows that at which frequency signals are dominant and how much. It is a qualitative

analysis, in which user can tell about the dominant frequency contents in signal. It is computed by the auto correlation of signal. Its direct block is available in LabVIEW. The power spectrum of signal acquired in this study is shown in figure below. In Figure 5.13 on X-Axis the frequency contents and on Y-axis the power of that frequency content in the signal. The Figure 5.13 shows that the maximum contents in signal is from 150 Hz to 500 Hz.

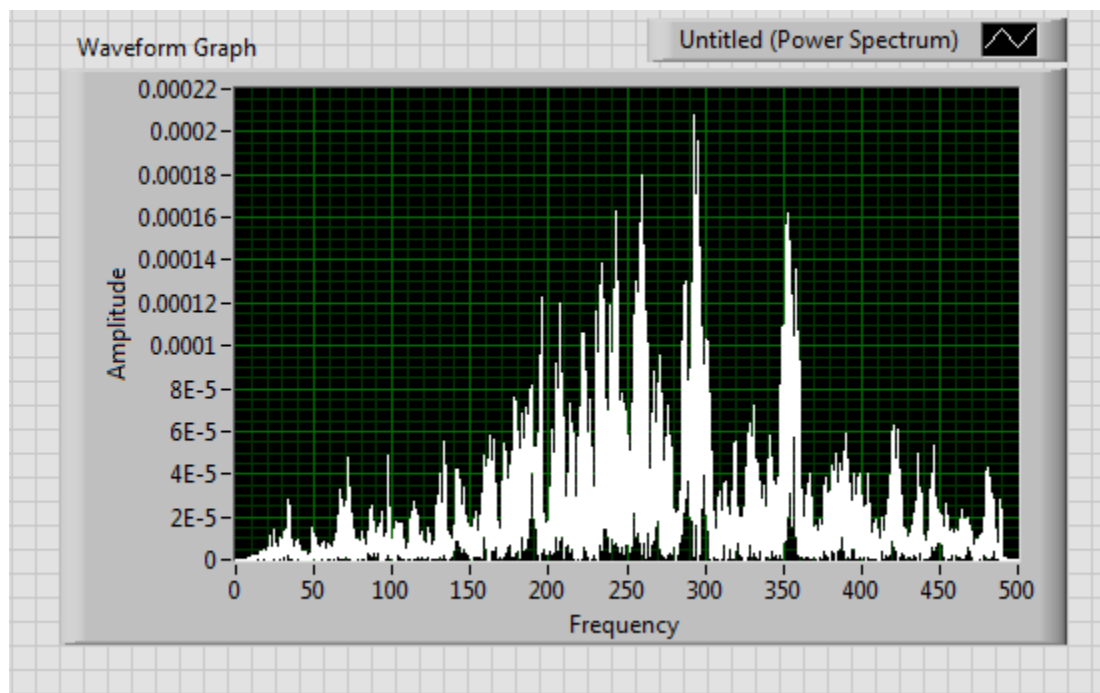


Figure 5.13 Power spectrum

5.6 Conclusion

SEMG signals were acquired and analyzed from three jaw muscles that were masseter, temporalis, submental with the help of DAQ card and LabVIEW at six different oral activities.

Temporalis muscle gave the largest value in all activity except water drinking. The values of four parameters were calculated and shows the highest value of temporalis muscle. The temporalis muscle shows the marginal increase in SEMG signal in terms of every parameter in activity B as compared to activity A. All other activities had a very good distinction on this muscle. The masseter muscle follows the same pattern as the temporalis muscle. The activity of masseter muscle is less than of temporalis muscle except only in two cases.

The submental muscle shows the most interesting pattern. It has the highest value in activity B. It also activates in various dynamic activities like activities C, D, E but in activity F which is a static activity has the lower value than the former activities.

RMS, MAV, VAR, SSI parameters were calculated. RMS shows the prominent signal. SSI is also a good parameter, but it is more suitable when it applied on activities which are separated by very less value. The overall analysis suggests that SEMG technique can applied to dentistry easily in various treatments.

5.7 Future Scope

- Data can be analyzed through the both sides of muscles. As it gives the more closeness to the natural oral activity of a person.
- This study can be applied to study the EMG activity of jaw muscles with artificial dentures.

- There are various types of artificial dentures, the performance of each of artificial denture can be studied through EMG.
- Intersubject adaptability to different type of dentures can be studied.

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